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U.S. Army Female Aviator Anthropometric, Clothing, and Cockpit Compatibility Study: Demography and Anthropometry of the Study Cohort

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Historically, aircraft design standards have been developed utilizing the 5th to the 95th percentile male. The current U.S. Army aviator population includes many females, who are compelled to operate aircraft that may be ill-fitting and consequently potentially unsafe. This comprehensive research program examined the female-machine match across a variety of Army aircraft and clothing ensembles. This cohort of female aviators is the largest of its kind using actual female pilots instead of general military females. The demographic characteristics of the 78 volunteers who participated in this study are comparable to other data on the female pilot population as a whole, making the group an excellent sample for studies of cockpit compatibility. The present report addresses the demography and anthropometry of the study cohort. Other reports in the series will address the various clothing and aircraft variables.

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Preface

This project was funded by the coordinated efforts of the Defense Women's Health Initiatives Program, the Aircrew Protection Division of the U.S. Army Aeromedical Research Laboratory, and the Science & Technology Directorate of the U.S. Army Natick Research, Development, & Engineering Center.

A number of people were instrumental in making this study possible. Ms. Elizabeth Ann Carson carried out the anthropometric measurements. CW5 Joel Voisine assisted in the location and acquisition of prospective volunteer female subjects assigned worldwide. Mr. Larry Burbank of the U.S. Army National Guard Bureau coordinated participation by National Guard volunteers. SGT Aracely Gregg assisted in data collection throughout testing. Ms. Sarah M. Donelson, Mr. Andy Higdon, and Dr. Samuel G. Shannon provided statistical advice. Mr. Steven Paquette and Ms. Nancy Bell provided anthropometric training at Natick for Ms. Carson. Ms. Carolyn Cave coordinated test subjects' travel finances. Ms. Mary Gramling and Ms. Janet Mauldin provided extensive and patient clerical support during report preparation.

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Of course, no test would have been possible without the voluntary participation of this enthusiastic cohort of female pilots. We thank them for their patience and willingness to help, and we thank their commanding officers for allowing their attendance.

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Introduction

The first U.S. Army female aviator was trained in 1973, and by 1994 there were about 424 female aviators, comprising 2.62% of the total Army aviator population (Mason and Shannon, 1994). Because females have a relatively recent entry into aviation service, the age and aircraft qualification distributions of this population are not comparable to male aviators (Shannon and Mason, 1994). In 1993, the U.S. Army changed its policy, permitting women to fly combat missions. This resulted in new opportunities for women to qualify in previously male-only aircraft, such as the AH-64 Apache, AH-1 Cobra, OH-58D Kiowa, and RAH-66 Comanche attack helicopters. At the same time, new aviation life support equipment (ALSE) items entered the inventory.

Because females are relatively recent additions to the pilot population, most existing U.S. Army aviation clothing, individual equipment, and rotary-wing cockpits were designed on the basis of male anthropometric data. Increasing representation of women in the Aviation Branch has introduced much greater variation in the body types to be accommodated in clothing and cockpits. In order to understand the needs of this more diverse group of pilots, the U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, and the Natick Research and Development Engineering Center (NRDEC), Natick, Massachusetts, undertook a study of cockpit and ALSE clothing compatibility in 1995. The objectives of the study were to gain a better understanding of female aviator anthropometry and to see how well existing equipment accommodated those body sizes and shapes for future design purposes. This report describes recruitment of the 1995 study cohort and presents summaries of its demographic and anthropometric characteristics. Subsequent reports in this series address the outcomes of fitting trials using members of this study cohort to test the ability of the Aircrew Battledress Uniform and an experimental Aircrew Cold Weather Clothing System to accommodate female pilots. Other reports address the outcomes of cockpit compatibility trials using members of this study cohort, the two aviator clothing systems, and the UH-1H Iroquois, OH-58A Kiowa, AH-64 Apache, UH-60A Black Hawk, and TH-67 Creek aircraft.

Sample acquisition

Subjects in this study were volunteers currently serving as Army aviators or undergoing aviator training. Two-hundred and ten female aviators stationed in the United States were contacted via mail after determining that an adequate sample size could not be obtained using women stationed only at Fort Rucker. The study was also advertised to flight school students, some of whom participated between training phases. Senior officers in the U.S. Army National Guard were informed of the study during their 1995 annual meeting.

Seventy-eight volunteers contacted the investigators and were scheduled for testing throughout the spring, summer, and fall of 1995. Volunteers traveled to USAARL to participate in 5-day testing periods. Many women had limited periods of time during which they could participate. Scheduling during the summer months was difficult. The investigators evaluated a

maximum of five subjects per week in five different aircraft types. Anthropometric and clothing evaluation lasted between 2.5 and 4.0 hours per subject. Assessments of accommodation in the aircraft wearing both summer and winter clothing configurations took another 3.5 to 5.0 hours. In addition, USAARL's UH-60 Black Hawk helicopter was involved in another laboratory study, so opportunities to test the females in this aircraft were limited. Due to the time commitment necessary to complete the study, some female officers were unable to attend, and several were forced to cancel their appointments because of unforeseen assignment commitments, such as peacekeeping deployments to Bosnia. Of the total 78 subjects participating in the anthropometric measurement and fit test portions of the study, two did not complete the cockpit evaluations due to inclement weather, illness, or sudden duty changes. The study cohort included women from U.S. Army bases in many states including Alaska and Hawaii. Three aviators were able to travel inexpensively from active duty posts in Korea.

Demography of the 1995 study cohort

Demographic data were collected on each test subject using the biographical questionnaire presented in Appendix A. The distributions of demographic variables in the study cohort are compared against those of female aviators in the U.S. Army Aviation Epidemiology Data Register (AEDR) for 1995 (Shannon, 1995) to determine the extent to which the study cohort may be considered representative of Army female aviators as a whole.

Military service component

The distribution of study cohort members by military component is compared against that of the 1995 AEDR female aviator population in Table 1. The study cohort was composed mainly of Regular Army pilots, most from Fort Bragg, North Carolina; Fort Campbell, Kentucky; Fort Carson, Colorado; and Hunter Army Airfield, Alabama.

Table 1.
Distribution of military component among the 1995 study cohort and the 1995 AEDR female aviator population.

Military component	Study cohort (%)	1995 female aviators (%)
Regular Army	60 (76.9)	277 (65.3)
Army Reserve	3 (3.8)	97 (22.9)
Individual Ready Reserve	0 (0.0)	20 (4.7)
Army National Guard	15 (19.2)	30 (7.1)
TOTAL	78	424

As can be seen in Table 1, the 1995 study cohort slightly overrepresents the Regular Army and Army National Guard and underrepresents the Army Reserve and Individual Ready Reserve relative to the prevailing distributions of female Army aviators in 1995 ($X^2 = 27.8351$, $p < .001$; Fisher's Exact $p < .001$).

Military rank

Table 2 shows the rank distribution of the study cohort compared to that of the AEDR 1995 female aviator population (Shannon, 1995). Rank composition of the study cohort was significantly different than that of the 1995 AEDR female aviators. Warrant officers are slightly overrepresented and commissioned officers slightly underrepresented in the study cohort ($X^2 = 10.3015$, $p < .001$; Fisher's Exact $p = .002$). There are also distributional differences between the study cohort and the 1995 AEDR female population for ranks within the commissioned officers and warrant officer groups; however, these differences are not statistically significant (Commissioned $X^2 = 7.225$, $p = .123$; Warrant $X^2 = .5258$, $p = .913$).

Table 2.
Distribution of rank among the 1995 study cohort and the 1995 AEDR female aviator population.

Rank	Study cohort (%)	1995 female aviators (%)
Officers		
2LT	10 (12.8)	33 (7.8)
1LT	8 (10.3)	75 (17.7)
CPT	18 (23.1)	131 (30.9)
MAJ	4 (5.1)	56 (13.2)
LTC	1 (1.3)	6 (1.4)
Subtotal Officers	41 (52.6)	301 (71.0)
Warrant Officers		
WO1	10 (12.8)	29 (6.8)
CW2	18 (23.1)	68 (16.0)
CW3	6 (7.7)	18 (4.25)
CW4	3 (3.8)	8 (1.9)
Subtotal Warrant Officers	37 (47.4)	123 (29.0)

Age

The ages of study cohort members ranged from 22 to 46. As shown in Table 3, two thirds of the women participants were between the ages of 25 and 34. Women over the age of 35 comprised 16.7% of the study cohort, but only 3 of these were 40 years or older. This was expected due to the relatively recent entrance of females into Army aviation service. There were no significant differences in age distribution between the study cohort and the 1995 AEDR females ($X^2 = 5.4857$, $p = .139$).

Table 3.
Distribution of age among the 1995 study cohort and the 1995 AEDR female aviator population.

Age groups in years	Study cohort (%)	1995 female aviators (%)
< 20	0 (0.0)	0 (0.0)
20 – 24	13 (16.7)	42 (9.8)
25 – 29	25 (32.0)	127 (30.0)
30 – 34	27 (34.6)	142 (33.5)
> 35	13 (16.7)	113 (26.7)
Total	78	424

Racial/ethnic background

Study cohort members identified the racial/ethnic category that best described themselves. Table 4 shows that most cohort members were white, non-Hispanic. Although comparable racial/ethnic data are not available in the AEDR database, the proportion of white, non-Hispanics in the study cohort was not significantly different from that of the 1989 active duty female pilot population reported by the Defense Manpower Data Center (Donelson & Gordon, 1991).

Table 4.
Distribution of racial/ethnic background among the 1995 study cohort and the 1989 active duty female pilot population (Donelson & Gordon, 1991).

Race/ethnic background	Study cohort (%)	1989 pilots (%)
White, non-Hispanic	74 (94.8)	254 (93.4)
Black, non-Hispanic	2 (2.6)	6 (2.2)
Hispanic	1 (1.3)	2 (0.7)
Asian/Pacific Islander	0 (0.0)	2 (0.7)
Native American	0 (0.0)	2 (0.7)
Mixed	1 (1.3)	6 (2.2)
Total	78	272

Years of military aviation service

Table 5 shows the years of military aviation service reported by study cohort members. Forty-three (55.2%) of the study cohort had served less than 5 years in Army aviation, 23 (23.1%) had 5 to 10 years, and the remaining 12 (12.8%) reported over 11 years of aviation service.

Table 5.
Distribution of years of aviation service for the 1995 study cohort.

Years of aviation service	Frequency	Percent	Cumulative percent
<1	4	5.1	5.1
1-2	23	29.5	34.6
3-4	16	20.6	55.2
5-6	7	8.9	64.1
7-8	7	8.9	73.0
9-10	9	11.5	84.5
11-12	2	2.6	87.1
13-14	4	5.1	92.2
15-16	3	3.9	96.1
18-19	3	3.9	100.0

Aircraft qualifications

Data on the aircraft qualifications of test subjects are summarized in Table 6. Cohort members reported all aircraft in which they had been qualified, and then identified their current primary aircraft. Most women were qualified in two or more aircraft. Several women were in flight training and identified the TH-67 Creek as their primary aircraft. As the U.S. Army's latest training helicopter, the TH-67 is used only during initial flight training, and prepares aviators for transition to any of the Army's rotary-wing aircraft.

Table 6.
Distribution of aircraft qualifications among the 1995 study cohort.

Aircraft	Qualification (%)	Primary aircraft (%)
UH-1	70 (89.7)	38 (48.7)
OH-6A	1 (1.3)	0 (0.0)
OH-58	13 (16.7)	4 (5.1)
CH-47	4 (5.1)	4 (5.1)
UH-60	17 (21.8)	16 (20.5)
AH-1	1 (1.3)	1 (1.3)
AH-64	1 (1.3)	2* (2.6)
TH-67	5 (6.4)	3** (3.8)
U-21	7 (9.0)	0 (0.0)
C-12/RC12	6 (7.7)	6 (7.6)
C-21	1 (1.3)	0 (0.0)
TH-55	4 (5.1)	0 (0.0)
EH-1	1 (1.3)	0 (0.0)
EH-60	1 (1.3)	1 (1.3)
OH-58D	3 (3.8)	3 (3.8)

*Includes one aviator currently undergoing transition to the AH-64.
**Students currently enrolled in flight school.

Prior to adoption of the TH-67 in October 1995, the U.S. Army used the TH-55 as its primary trainer, followed more recently in 1987 by the UH-1 Iroquois. The majority of study cohort members (n=70, 89.7%) were qualified to fly the UH-1. With the decision to discontinue use of the UH-1 as the mainstay in U.S. Army helicopters, many pilots, both male and female, have undergone transitions to other aircraft. While 48.7% of the study cohort members still report the UH-1 as their primary aircraft, most of the women have been offered transitions to the UH-60 Blackhawk. Two of those in the study opted for the AH-64 Apache, and three for the

electronically enhanced OH-58D Kiowa Warrior. Those pilots reporting fixed wing as their primary aircraft generally were very experienced Army aviators flying reconnaissance and special duty missions.

Discussion

It is difficult, if not impossible, to ensure a representative sampling when test participation is wholly voluntary, potential subjects are globally dispersed, and the entire population is itself relatively small in number. Nevertheless, the demographic characteristics of the 1995 female pilot study cohort closely approximate those of female aviators in the 1995 AEDR database in all but two respects: the study sample slightly underrepresents Reserve components relative to Active Duty and National Guard, and slightly overrepresents Warrant Officers relative to Commissioned Officers. However, given the good concordance between the study cohort and actual pilot population in terms of age and racial/ethnic distributions, and considering the relatively large number of subjects with 5 or more years of aviation experience (45%), this test sample should provide a sound basis for the evaluation of aviator clothing ensembles and cockpit compatibilities. Furthermore, this study represents the only such examination of clothing/cockpit issues reported to date using actual female pilots as test subjects.

Anthropometry of the study cohort

Measurement procedures

The first portion of the 1995 Female Aviator Anthropometric, Clothing, and Cockpit Compatibility Assessment consisted of 36 body measurements made using standardized anthropometric protocols from the U.S. Army Anthropometric Survey (ANSUR) (Clauser et al., 1988; Gordon et al., 1989). The specific body dimensions chosen for measurement were selected for two purposes: 1) to obtain an anthropometric profile of the female pilot population, and 2) to facilitate ergonomic evaluations and quantitative recommendations to improve aircrew protective clothing and crewstation geometries. Table 7 lists the 36 body measurements made on the 1995 cohort, and Appendix B outlines the measuring protocols.

Detailed landmark and measurement definitions, line drawings and photographs of the measurements listed in Table 7 can be found in either the ANSUR measurer's handbook (Clauser et al., 1988) or the ANSUR summary report (Gordon et al., 1989). All measurements were taken on the right side of the subject's body. Thumbtip reach was measured and recorded three times on each subject and the average of the three trials was used in data analyses for this study. Three variables, crotch height, buttock-popliteal length, and popliteal height, have had 10 mm added to the originally recorded values to compensate for the width of the anthropometer blade. Randomly chosen measurements were repeated on most subjects to track and manage observer error. When differences between the first and second values of repeated measurements exceeded allowable margins of error in the ANSUR protocols (Gordon et al., 1989), subject positioning was checked and the measurement repeated a third time.

Table 7.
Body measurements made on the 1995 female aviator study cohort.

Abdominal ext. depth, sitting	Foot length	Popliteal height
Acromial height, sitting	Functional leg length	Sitting height
Bideltoid breadth	Hand circumference	Sleeve outseam
Bizygomatic breadth	Hand length	Stature
Buttock circumference	Head breadth	Thigh circumference
Buttock-knee length	Head circumference	Thigh clearance
Buttock-popliteal length	Head length	Thumbtip reach
Cervicale height	Hip breadth, sitting	Vertical trunk circ (USA)
Chest circumference	Knee height, sitting	Waist circ (natural indent)
Crotch height	Lower thigh circumference	Waist circ (omphalion)
Eye height, sitting	Menton-Sellion length	Waist height (omphalion)
Foot breadth, horizontal	Neck circumference, base	Weight

Summary statistics for the 1995 study cohort

Summary statistics for each of the 36 body measurements made on the 1995 female aviator study cohort are reported below in Table 8. All values are in millimeters or kilograms, and variables have been arranged in alphabetical order for convenience. Only a limited number of percentiles are reported on this sample due to its relatively small size (n=78). The 1st and 99th percentiles are not reported, for example, because their 95% confidence intervals overlap with those of the 5th and 95th percentiles, making the minimum and maximum values more useful in visualizing sample extremes.

Kolmogorov-Smirnov tests for goodness of fit to a Normal distribution indicate that only head circumference departs significantly from a Normal probability distribution ($z = 1.4$, $p = .04$). The head circumference distribution for the 1995 female aviator study cohort is skewed slightly to the right.

Table 8.
Anthropometry of the 1995 female aviator study cohort (n=78), in mm.

Measurement	Mean	Std Dev	Min	5th %ile	50th %ile	95th %ile	Max
Abd ext dpth	208.9	26.0	168	174.9	201.0	254.5	282
Acrom ht sit	580.5	21.9	534	538.0	579.5	618.1	627
Bideltoid br	437.3	25.4	386	392.9	435.5	482.1	511
Bizygo br	131.8	4.7	121	125.0	132.0	140.0	141
Butt circ	996.6	66.6	873	887.8	994.0	1126.2	1161
Butt-knee length	590.9	26.4	544	549.0	588.5	637.2	677
Butt-pop length	489.5	23.9	444	451.9	486	533.4	562
Cervicale ht	1421.6	46.0	1310	1352.7	1417.5	1516.3	1543
Chest circ	929.2	64.5	785	829.0	925.5	1053.3	1103
Crotch ht	784.5	31.7	723	740.9	781.5	857.5	892
Eye ht, sitting	757.6	24.5	709	716.9	757.0	796.1	814
Foot br	91.5	4.3	82	85.0	92.0	99.0	102
Foot length	244.5	11.7	217	225.0	245.0	266.0	283
Func leg length	1067.9	45.0	971	998.0	1065.5	1144.0	1189
Hand circ	191.8	7.6	174	177.0	191.0	206.1	208
Hand lgth	179.7	10.5	154	163.8	179.0	199.2	205
Head br	146.5	4.4	136	140.0	146.0	154.0	160
Head circ	563.8	16.1	537	544.0	559.0	598.1	606
Head length	191.2	6.2	180	182.0	191.0	201.0	211
Hip br, sitting	420.2	34.7	343	363.0	420.5	491.1	510
Knee ht, sitting	513.6	22.2	466	480.5	510.0	556.2	581
Lower thigh circ	389.8	26.2	326	346.9	388.0	436.4	462
Men-Sell length	114.7	5.7	102	103.0	115.0	125.0	129
Neck circ	377.3	20.4	341	346.9	378.0	416.2	430

Table 8 (continued).

Anthropometry of the 1995 female aviator study cohort (n=78), in mm.

Measurement	Mean	Std Dev	Min	5th %ile	50th %ile	95th %ile	Max
Popliteal ht	404.7	21.2	354	372.8	402.0	441.2	469
Sitting ht	882.2	28.4	820	834.0	881.0	930.0	933
Sleeve outseam	545.7	22.3	498	507.9	547.5	582.4	602
Stature	1665.0	53.8	1548	1579.7	1662.5	1760.4	1810
Thigh circ	600.4	52.7	500	520.2	594.5	698.7	740
Thigh clear	154.9	12.4	130	134.9	154.0	179.1	182
Thumbtip rch	806.2	46.6	713	726.1	802.8	888.4	931
Vert trunk circ	1560.4	60.2	1431	1469.9	1561.5	1666.3	1722
Waist circ-NI	743.3	66.2	620	660.9	729.0	869.3	937
Waist circ-OM	814.0	84.0	638	691.0	802.0	959.5	1086
Waist ht - OM	1000.9	40.5	916	935.7	997.5	1083.5	1128
Weight (kg)	64.0	8.7	47.6	50.0	63.3	80.6	86.5

It is difficult to know whether the body dimensions of the 1995 study cohort are representative of the 1995 female pilot population as a whole. Because all 78 study subjects were volunteers rather than a random sample of female pilots, it is possible that body size may have influenced some pilots' decisions to volunteer. For example, pilots whose body dimensions are close to the Initial Entry Rotary Wing (IERW) anthropometric limits (Chase, 1990) or who are already flying with waivers to anthropometric selection criteria, may not wish to draw attention to themselves by participating in a study that may highlight the problems body size or shape might cause in performing flying duties. If, on the other hand, pilots are having difficulties in the fit of their personal equipment or crewstations, they may be particularly motivated to participate in a study that would generate data to improve the situation.

At the time of this study, the prevailing IERW anthropometric selection criteria were as depicted in Table 9 (Chase, 1990).

Table 9.
Anthropometric criteria for initial entry rotary wing training (Chase, 1990).

Flight Classes 1/1A/2/2F	Flight Class 2S (Aeroscout; OH-58)
Crotch Height ≥ 750 mm	Crotch Height ≥ 750 mm
Span ≥ 1640 mm	Span ≥ 1640 mm
Sitting Height ≤ 1020 mm	Sitting Height ≤ 950 mm

*There is also a general Army requirement that stature be ≥ 1626 mm and ≤ 1930 mm; however, this limitation for IERW training is not as strictly enforced as the others (Mason, 1996)

It is noteworthy that 9 of 78 (11.5%) female volunteers for the 1995 study had body dimensions below the IERW crotch height minimum of 750 mm, whereas only 5 of 487 male pilots measured in 1988 (<1%) had body dimensions outside any of the aviation-specific anthropometric requirements. This difference suggests that there may be relatively fewer male pilots flying on anthropometric waivers, and/or that small female pilots may have volunteered at unusually high rates for the 1995 study. Furthermore, the number of female pilots in the 1995 study cohort who were outside the IERW anthropometric requirements may actually have been higher than the 11.5% estimated on crotch height alone. Span measurements were mistakenly deleted from the 1995 study before data collection began, so the 1995 study participants cannot be classified as to whether or not they met the IERW span minimum.

Comparative anthropometric data

Anthropometric surveys of military females are few in number, and data on actual female aviators are virtually nonexistent. Although the U.S. Air Force 1968 survey (Clauser et al., 1972) and the U.S. Army 1977 survey (Churchill et al., 1977) focused on female military personnel, both studies predate substantial recruitment of female aviators. The most recent large-scale military survey is the 1988 ANSUR survey, in which 132 body dimensions were measured for approximately 3500 female and 5500 male active duty soldiers (Gordon et al., 1989). During the ANSUR survey, all pilots available at each of six U.S. Army Forces Command (FORSCOM) posts were measured and a special visit was made to Fort Rucker to measure pilots. While this approach provided the aviation community with an excellent anthropometric profile of male aviators (n=487), only nine female aviators were captured in the sample. Because the number of female aviators available to participate in the ANSUR survey was so small, it could not provide a comparably large database on actual female pilots. Instead, a simulated female pilot database (n=334) was created using test subjects from the general Army population who met 1989 IERW criteria (which were the same as those in Table 9), and whose demographic profiles matched the 1989 *active duty* Army female pilot population (Donelson & Gordon, 1991).

While the simulated female pilot database derived from ANSUR is the best available guess at the anthropometric profile of female Army pilots in 1989, it has two shortcomings that make further specialized studies of female pilots very desirable. Firstly, significant numbers of Army

females receive waivers of various flight school entrance criteria, yet there were insufficient data available on the frequency and magnitude of anthropometric waivers in 1989 to replicate this effect in the construction of the ANSUR simulated pilot database. Secondly, the ANSUR survey was restricted to *active duty* Army only, and the simulated female pilot database was constructed to match the demographic profile of *active duty* female pilots, whereas a substantial proportion of Army pilots in 1995 were serving in the Reserve and National Guard components.

Table 10 reports the results of t-tests between comparable body dimensions from the ANSUR simulated female pilot database (Donelson & Gordon, 1991) and the 1995 study cohort of 78 actual female pilots. When sample variances differed at the .05 level or better, t-tests were based upon separate variance estimates and Satterthwaite's formula for degrees of freedom (StataCorp, 1997). Differences that are statistically significant at the .05 level or better (after Bonferroni correction for multiple comparisons) are shaded in Table 10.

Table 10.
Anthropometric comparison of 1988 female pilot eligibles and the 1995 study cohort of actual female pilots, in mm.

	1988 (n=334)		1995 (n=78)			
Variable	**Mean**	**SD**	**Mean**	**SD**	*t*	*p**
Abdominal ext depth, sitting	227.93	28.66	208.91	28.98	5.37	.000
Acromial height, sitting	578.46	23.97	580.49	21.94	-0.68	.495
Bideltoid breadth	439.15	22.18	437.31	25.43	0.64	.521
Bizygomatic breadth	131.44	5.02	131.76	4.73	-0.51	.613
Buttock circumference	989.01	61.78	996.65	66.61	-0.97	.333
Buttock-knee length	600.21	20.87	590.91	26.46	2.90[s]	.005
Buttock-popliteal length	492.17	18.45	489.46	23.90	0.94[s]	.350
Cervicale height	1453.32	41.99	1421.64	46.06	5.89	.000
Chest circumference	924.78	68.47	929.15	64.47	-0.51	.608
Crotch height	791.67	27.10	784.46	31.69	2.05	.041
Eye height, sitting	768.48	27.04	757.58	24.48	3.26	.001
Foot breadth	90.44	4.48	91.46	4.27	-1.82	.069
Foot length	247.81	9.42	244.47	11.72	2.34[s]	.021
Functional leg length	1037.99	32.78	1067.87	44.96	-5.54[s]	.000
Hand circumference	188.22	7.79	191.76	7.57	-3.62	.000
Hand length	182.49	7.15	179.68	10.55	2.24[s]	.028
Head breadth	145.11	4.80	146.53	4.45	-2.38	.018

[s] Indicates t-test conducted using separate variance estimates.
*Significant differences (after Bonferroni correction for 36 comparisons) are shaded.

Table 10 (continued).
Anthropometric comparison of 1988 female pilot eligibles
and the 1995 study cohort of actual female pilots, in mm.

	1988 (N=334)		1995 (N=78)			
Variable	**Mean**	**SD**	**Mean**	**SD**	***t***	***p****
Head circumference	547.88	13.31	563.85	16.09	-8.14 ^{s}	.000
Head length	188.16	6.41	191.15	6.18	-3.75	.000
Hip breadth, sitting	397.80	27.54	420.26	34.72	-5.34 ^{s}	.000
Knee height, sitting	528.29	17.31	513.62	22.19	5.46 ^{s}	.000
Lower thigh circumference	382.06	27.86	389.77	26.16	-2.23	.027
Menton-sellion length	114.55	6.07	114.71	5.66	-0.20	.841
Neck circumference, base	349.61	15.87	377.31	20.36	-11.24 ^{s}	.000
Popliteal height	400.60	(16.21)	404.68	(21.21)	-1.59 ^{s}	.114
Sitting height	882.79	28.09	882.21	28.36	0.17	.868
Sleeve outseam	560.95	19.41	545.67	22.33	6.08	.000
Stature	1680.23	45.28	1665.05	53.85	2.31 ^{s}	.023
Thigh circumference	587.49	45.77	600.45	52.69	-2.18	.029
Thigh clearance	159.49	12.60	154.90	12.41	2.90	.004
Thumbtip reach	750.17	25.70	806.19	46.63	-10.25 ^{s}	.000
Vertical trunk circumference	1577.71	62.75	1560.37	60.26	2.21	.028
Waist circumference, NI	741.53	71.24	743.30	66.24	-0.20	.842
Waist circ., omphalion	816.53	89.87	813.96	83.96	0.23	.818
Waist height, omphalion	1012.73	33.57	1000.90	40.51	2.40 ^{s}	.018
Weight (kg)	65.51	8.56	64.03	8.72	1.37	.170

^{s} Indicates t-test conducted using separate variance estimates.
*Significant t-values (after Bonferroni correction for 36 comparisons) are shaded.

In general, the 1995 study cohort is smaller in body size than the 1988 simulated female pilot database. The 1995 pilots are, on average, 15 mm shorter in stature, 12 mm shorter at the waist (omphalion), and 7 mm shorter at the crotch than the 1988 simulated pilot sample. The 1995 pilots are also 1.5 kg lighter than the 1988 sample on the average. None of these differences are statistically significant at the .05 level after Bonferroni correction.

In terms of sitting height and seated acromial height, the 1995 and 1988 means are virtually identical. However, the seated cervicale height mean of the 1995 sample is 31 mm smaller than that of the 1988 sample and the 1995 seated eye height mean is 11 mm smaller than that of the 1988 sample. Both of these differences are statistically significant.

Leg and arm dimensions also exhibit some interesting contrasts. Crotch height, knee height seated, and buttock knee length means are all smaller in the 1995 pilots than in the 1988 database, although only knee height is significantly so. However, the 1995 mean for functional leg length is 30 mm *larger* than that of the 1988 sample, a difference that is statistically significant. It is tempting to hypothesize that the 1995 cohort gets its greater functional leg length from contributions by the buttocks; however neither buttock-knee length nor buttock-popliteal length are larger in the 1995 sample than in the 1988 sample.

Functional (thumbtip) reach is also significantly (56 mm) larger in the 1995 cohort than the 1988 simulated pilot sample, but it is hard to understand where this differences arises because sleeve outseam (acromion to radial styloid distance) is 15 mm *shorter* in the 1995 sample; hand length is 2.8 mm shorter in the 1995 sample as well. Exclusion of span data on the 1995 cohort is particularly regrettable, as it is a much more reliable measurement than thumbtip reach (Ch 7, Gordon et al., 1989).

Discussion

Overall body size is slightly smaller in the 1995 cohort, which might be expected if anthropometric waivers to IERW criteria result in a female pilot population that is smaller than would be expected based upon IERW selection limits alone, or if smaller female pilots were more motivated to volunteer for the 1995 study. However, despite a general pattern of 1995 means being similar to or smaller than those of 1988, several very important functional measurements seem to be much larger in the 1995 sample, including functional leg length and functional (thumbtip) reach.

It is tempting to attribute the larger leg and arm reach means in the 1995 sample to selective influences apart from IERW criteria, arising from anthropometric limitations in existing crewstation geometries, and resulting in task-critical body dimension distributions that may be unique to the pilots who can successfully fly the aircraft. However, in this case, any meaningful interpretation of the reach differences is made difficult by the fact that related body dimensions do not exhibit the same pattern of differences between the 1995 and 1988 samples - just the opposite trend, in fact.

An alternative explanation for the unusual leg and arm reach values in the 1995 sample is that they were measured with slightly different techniques than were used in the 1988 study, even though the measurement definitions were the same. This is a common problem when comparing anthropometric values gathered by different measuring teams, and the more difficult the measurement is to conduct, the greater the differences attributable to measurement technique rather than body sizes differences per se.

Table 11.
Thumbtip reach statistics from recent studies of military females, in mm.

Study	N	Mean	Std. Dev.	5th %ile	95th %ile
1995 Army pilot cohort	78	806.2	46.6	726	888
1995 UK simulated female pilots (Nammari, 1998)	269	776.2	25.0	744	820
1988 Army simulated female pilots (Donelson & Gordon, 1991)	334	750.2	25.7	711	794
1995 UK females (Aplin & Nammari, 1995)	1002	738.7	38.1	680	804
1988 Army females (Gordon et al., 1989)	2208	734.6	36.4	677	797
1977 Army females (Churchill et al., 1977)	300	711.7	45.3	640	790
1968 USAF females (Clauser et al., 1972)	1905	741.3	38.8	677	804

Thumbtip reach is among the most difficult functional measurements to standardize as it requires that subjects maintain contact between their shoulder blades/buttocks and the wall, and the degree to which they do so greatly affects the measurement outcome (Clauser et al., 1986). Many anthropometrists ensure consistent subject/wall contact by placing their hand on the front of the subject's shoulder when the measurement is made, and this method was employed in the ANSUR survey (Clauser et al., 1988 or Donelson & Gordon, 1991) and defined in this study. However, variations in the amount of pressure habitually used by the anthropometrist could contribute to consistent differences in measured reach values that are not due to body size. In this study, it is possible that lighter contact was made by the sole anthropometrist and her subjects than was used in the ANSUR survey, thus permitting more rotation at the shoulder, and resulting in a reach mean that is not only larger than the 1988 simulated sample, but larger than all other recent studies of military females as well (Table 11).

Functional leg length is also difficult to standardize between measuring teams, even with comparable protocols, owing to differences in the degree of knee extension requested by the anthropometrist and to difficulties in standardizing the alignment of the anthropometer along the leg and location/pressure of the anthropometer blade on the buttocks (Clauser, McConville, and Gordon, 1986).

Table 12.
Functional leg length statistics from recent studies of military females, in mm.

Study	N	Mean	Std. Dev.	5th %ile	95th %ile
1995 Army pilot cohort	78	1067.9	45.0	998	1144
1988 simulated Army female pilots (Donelson & Gordon, 1991)	334	1038.0	32.7	990	1097
1988 Army females (Gordon et al., 1989)	2208	1021.0	49.1	932	1094
1977 Army females (Churchill et al., 1977)	300	1089.2	57.8	996	1186

In the ANSUR survey of 1988, the trochanterion landmark was used to align the anthropometer consistently with the leg (Clauser et al., 1988). However, this protocol appears to result in a slightly lower terminus for the anthropometer blade on the buttocks than was used in previous Army surveys where the posterior waist landmark or no landmark was used to orient the anthropometer (Laubach, McConville, and Churchill, 1977; Churchill et al., 1977). As no other measurement on the 1995 study cohort required marking of the trochanterion landmark, it seems likely that functional leg length was measured in a fashion similar to that used in the 1977 Army survey (Churchill, et al., 1977), which resulted in slightly larger values of functional leg length. That would explain how the functional leg length could be so much longer in the 1995 sample without correspondingly larger leg segment values.

Measuring technique differences such as those noted above should not cast doubt upon the reliability and validity of the 1995 cohort data as a whole. Even when anthropometrists are properly trained, careful, and consistent in their measuring techniques, subtle differences among studies can arise. The anomalies in thumbtip reach and functional leg length values discussed above concern particularly difficult measurements. These data highlight the benefits of frequent measurer standardization trials, repeated measurement of tricky dimensions like thumbtip reach and the use of on-site data entry software that prompts the anthropometrist to remeasure the subject whenever unusual values are detected.

Conclusions

The 1995 study cohort of female pilots is the largest of its kind using actual female pilots instead of general military females. The demographic characteristics of the 78 volunteers who participated in this study are comparable to other data on the female pilot population as a whole, and 45% of the cohort have 5 or more years experience in Army aviation, which makes the group an excellent sample for studies of cockpit compatibility reported in subsequent technical papers. At least 11.5% of the study sample have body dimensions outside the stated IERW anthropometric requirements for pilots, which is a larger proportion than observed in previous studies of male pilots, but may not be unusual for the current female flying population.

Anthropometric data are reported on 36 body dimensions for the study sample. However, the relatively small sample size and volunteer method of subject recruitment used in this study prohibit firm inferences about body size distributions of all female pilots from this cohort alone. Furthermore, there is some indication that subtle differences in the measurement techniques used for thumbtip reach and functional leg length in this study may render consistently larger values than comparable data from other female surveys. That said, the 1995 study cohort data are the *only* available anthropometric data on actual female Army pilots, and comparisons with the 1988 simulated female pilot database from the ANSUR survey suggest that statistically simulated databases using military females, IERW entrance criteria, and demographic matching may slightly overestimate the body size distributions of actual female pilots due to the effects of waivers granted to IERW criteria.

In any case, the range of anthropometric variability provided by these test subjects is more than adequate to provide a fair test of the ability of aviator clothing, equipment, and crewstations to accommodate actual female pilots. Subsequent reports in this series will address the outcomes of these tests.

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Appendix A.

Biographical questionnaire.

SUBJNO: __________ TODAY'S DATE: ______________

Birthdate: _____ Day/ _____ Month/ _____ Year (e.g., 19/07/71)

Age: _____ Years

Military Component: _____ Regular Army _____ Army Reserve _____ National Guard

Rank/Grade: _____ / _____ (e.g., LTC/05)

Time in Service (please circle one):

less than 1 yr   1-2 yrs   3-4 yrs   5-6 yrs   7 yrs or more

Total Aviation Service: _____ years _____ months (e.g., 12 years, 3 months)

Total Flight Hours: ________ hours

Aircraft Qualifications:

_____ UH-1   _____ OH-58   _____ CH-47   _____ UH-60

_____ AH-1   _____ AH-64   _____ OV-1   _____ U-21

_____ C-12   _____ Other

What racial category best describes you:
_____ White, non-Hispanic
_____ Black, non-Hispanic
_____ Hispanic
_____ Asian/Pacific Islander
_____ Native American
_____ Mixed: (specify:________________________________)
_____ Other: (specify:________________________________)

Do you presently have a contagious skin condition?
_____ No   _____Yes, explain:____________________________

Measurement Record

SUBJNO: ______________ **DATE:** ______________

Landmark checklist (cross out when marked):

Menton	Stylion	Trochanter
Sellion	Bustpoint	Suprapatella
Lateral neck	Waist (NI)	2nd metacarpal protrusion
Trapezius	Waist (O)	5th metacarpal protrusion
Acromion	Buttock point	1st metatarsal protrusion
Midshoulder	Gluteal furrow height	5th metatarsal protrusion
Cervicale		

Standing measurements

Weight		Neck circ		Lo thigh circ	
Stature		Chest circ		Slv outseam	
Cervicale ht		Waist circ-NI		VTC-USA	
Waist ht (O)		Waist circ-O		Foot br	
Crotch ht		Butt circ		Foot length	
		Thigh circ		Thumb rch	1)
					2)
					3)

Seated measurements

Hand circ		Hip br		Knee ht, sit	
Hand lgth		Abd ext dpth		Popliteal ht	
Head circ		Bideltoid br		Thigh clear	
Head length		Sitting ht		Butt-knee length	
Head br		Eye ht, sit		Butt-pop length	
Bizygo br		Acrom ht sit		Func leg length	
MenSell length					

Observer error measurements: Standing measurements

Weight		Neck circ		Lo thigh circ	
Stature		Chest circ		Slv outseam	
Cervicale ht		Waist circ-NI		VTC-USA	
Waist ht (O)		Waist circ-O		Foot br	
Crotch ht		Butt circ		Foot length	
		Thigh circ		Thumb rch	1)
					2)
					3)

Seated measurements

Hand circ		Hip br		Knee ht, sit	
Hand length		Abd ext dpth		Popliteal ht	
Head circ		Bideltoid br		Thigh clear	
Head length		Sitting ht		Butt-knee L	
Head br		Eye ht, sit		Butt-pop L	
Bizygo br		Acrom ht sit		Func leg L	
MenSell length					

Appendix B.

Description of measurements for the 1995 U.S. Army Female Aviator Anthropometric, Clothing, and Cockpit Compatibility Assessment (Clauser et al., 1988).

Measurement	Anthropometric equipment	Landmarks	Position of subject	Description
Abdominal extension depth, sitting	Beam caliper	(Abdominal point, anterior)	Anthropometric sitting position; right hand on left shoulder	Standing to the right of the subject, place the fixed blade of the beam caliper on her back at the same level as the most anterior point of her abdomen. At the maximum point of quiet respiration of the subject, take the horizontal distance between these two points, making sure that the blades only lightly touch the skin.
Acromial height, sitting	Half anthropometer	Acromion, right	Anthropometric sitting position; arms flexed 90° at elbows	Ensure that the subject has established a normal respiratory cycle and is not moving her shoulders. Stand behind her, anchoring the base of the half anthropometer firmly to the sitting table, and raise the blade so that it is barely touching the drawn acromion landmark on her right shoulder. Measure the vertical distance to this point.
Bideltoid breadth	Beam caliper	None	Anthropometric sitting position; arms flexed 90° and elbows touching sides	Stand behind the subject and find the maximum horizontal distance between the outside of the deltoid muscles by gently sliding the caliper blades up and down the upper arms. The blades should not compress any tissue, and the subject must be at the maximum point of quiet respiration.
Bizygomatic breath	Spreading caliper	None	Seated; jaw unclenched; head facing forward; eyes closed, if desired	Standing in front of the subject, brush the tips of the spreading caliper along the zygomatic arches to ascertain the maximum horizontal breadth between the cheekbones. Use only very light pressure.
Buttock circumference	Steel tape	Buttock point, right and left laterals, (posterior)	Standing with heels together; arms relaxed; hands pulling up slightly on sides of shorts	Kneel at the right side of the subject, and visually assess the maximum point of protrusion of the posterior of the buttocks. Pass the steel tape loosely across the lateral buttock points and the posterior so that contact between the tape and skin is maintained, but no compression occurs. The tape must be parallel to the floor over the entire circumference; use a mirror to ensure this in the back.
Buttock-knee length	Half anthropometer, buttock plate on sitting table	(Knee point, anterior)	Anthropometric sitting position; arms resting in lap; back lightly touching buttock plate	Slide the buttock plate up so that it touches the subject's posterior buttocks points and lock the plate to the sitting table. Anchor the base of the half anthropometer to the vertical surface of the buttock plate, and slide the blade forward to measure the horizontal distance from the plate to the furthest protruding part of the subject's right knee.

Measurement	Anthropometric equipment	Landmarks	Position of subject	Description
Buttock-popliteal length	Half anthropometer, buttock plate on sitting table	None	Anthropometric sitting position; arms resting in lap; back lightly touching buttock plate	Anchor the base of the half anthropometer to the buttock plate, as in Buttock-Knee Length. Measure the horizontal distance between this plate and the popliteal fossa at the back of the knee without compressing any tissue. Ten mm will be added to this measurement in the database to compensate for the width of the anthropometer blade.
Cervicale height	Anthropometer	Cervicale	Anthropometric standing position; arms resting at sides; head in Frankfort plane	Stand to the right and slightly behind the subject and ensure her head is in the Frankfort plane. Measure the vertical distance between the floor and the cervicale landmark using an anthropometer.
Chest circumference	Steel tape	(Bustpoint/ thelion)	Anthropometric standing position; arms resting at sides	Ask the subject to raise her arms. Pass the tape under her arms at the level of the bustpoint. Check in the mirror to make sure the tape is parallel to the floor across her back, and use only enough pressure to keep the tape in contact with the skin. Allow the subject to breathe normally several times and watch the tape for the circumference at the maximum point of respiration.
Crotch height	Anthropometer	None	Anthropometric standing position; heels together	The subject steps over the anthropometer blade and draws it up between her legs until it comes into contact with the crotch. She then brings her heels together and assumes the Anthropometric Standing Position, while the measurer ensures that the blade is firmly in position. The vertical distance is read and the subject steps away from the anthropometer. Ten mm will be added to this measurement to compensate for the width of the anthropometer blade.
Eye height, sitting	Half anthropometer	(Ectocanthus, right)	Anthropometric sitting position; head in Frankfort plane; eyes closed	Position the subject to ensure correct alignment of her head, and place the half anthropometer to her right on the sitting table. Stand to the right of the subject and level the anthropometer blade to the height of the corner of her right eye. Keeping the anthropometer at a safe distance, bend to the level of the subject's ectocanthus and sight along the bottom of the blade to read the vertical distance without touching the subject.
Foot breadth, horizontal	Right and left foot boxes	First and fifth metatarso-phalangeal protrusions	Standing with one foot in each foot box; weight evenly distributed	Kneeling at the right of the subject, carefully lift and place her right foot so that the heel is only lightly touching the back of the right foot box and the fifth metatarsophalangeal protrusion touches the side of the box. The inside of the foot should run parallel to the long axis of the box. Set a block at the first metatarsophalangeal protrusion and use its straight edge to read the horizontal breadth foot box scale.

Measurement	Anthropometric equipment	Landmarks	Position of subject	Description
Foot length	Right and left foot boxes	Fifth metatarso-phalangeal protrusion	Standing with one foot in each foot box; weight evenly distributed	Position the subject's right foot in the foot box in exactly the same manner as in foot breadth, horizontal. Place a block at the tip of the longest toe, and establish the length of the foot using the straight edge of the block to read the foot box scale.
Functional leg length	Functional leg length anthropometer, bench (479 mm vertical distance from the floor)	Trochanter	Seated erect at edge of bench; right leg extended; left leg bent back below bench; right hand resting on left shoulder; back is straight	Ensure that the subject is seated at the edge of the bench, and ask her to place her right foot flat against the footrest of the anthropometer. Push out or draw in the anthropometer to achieve full right leg extension of the subject, and tilt the anthropometer down to run parallel to the outside of the right leg. The anthropometer will pass over the trochanter landmark. Ask the subject to sit up straight, and measure the distance between the footrest and the point on the back of the subject's body that is in line with the anthropometer. The blade should only lightly touch the subject on her back.
Hand circumference	Steel tape, 8 mm board	Metacarpale II, V, right	Seated on bench to the left of the sitting table; right palm resting on table with phalanges raised on 8mm board; fingers held together; thumb at 45 degree angle from fingers	Press the subject's right hand into contact with the table, but do not let the subject tense or flex her hand. Gently pass the tape under her fingers at the level of the drawn metacarpale landmarks. The tape will pass over the landmarks, and only light pressure should be exerted to keep the tape in contact with the skin.
Hand length	Poech sliding caliper, 8 mm board	Stylion, (Dactylion III, right)	Seated on bench to the left of the sitting table; right palm resting on table with phalanges raised on 8 mm board; fingers held together; thumb at 45 degree angle from fingers	The subject retains the same hand position as in Hand Circumference. Ensure that the fingers are not flexed, and position the fixed blade of the Poech caliper at the drawn Stylion landmark. Place the sharp tip of the blade close to the mark, and adjust the sliding blade to lightly touch the tip of the dactylion III, or middle finger.
Head breadth	Spreading caliper	None	Seated; head facing straight forward	Stand behind the subject and brush the tips of the caliper back and forth to find the maximum breadth of the head above the ears. The caliper tips should be in light contact with the head, compressing the hair.
Head circumference	Steel tape	None	Seated; head facing straight forward	Stand on the subject's right and sight the level of maximum posterior protrusion of the head. Pass the steel tape over the supraorbital ridges (just above the eyebrows), and the posterior protrusion to obtain the maximum circumference of the subject's head. The tape should be held tight enough to compress the subject's hair but not her forehead skin.

Measurement	Anthropometric equipment	Landmarks	Position of subject	Description
Head length	Spreading caliper	(Glabella)	Seated; head facing straight forward	Stand at the right side of the seated subject and position one tip of the spreading caliper between the brow ridges or glabella. This arm of the caliper will remain fixed, but should only be in light contact with the tip. Adjust the other caliper arm to find the maximum horizontal distance between the glabella and the opisthocranion, or most posterior point on the back of the head. Brush the moving tip up and down to locate the widest point, compressing the hair.
Hip breadth, sitting	Beam caliper	None	Anthropometric sitting position; arms relaxed and held slightly away from sides; feet and knees together	Ensure that the subject's knees are not splayed outwards, and that her arms are slightly away from her sides. Stand in front of the subject, hold the beam caliper at a 45 degree angle, and gently brush the blades up and down the lateral sides of the subject's hips or thighs (whichever is the broadest) to find the greatest horizontal breadth.
Knee height, sitting	Half anthropometer	Suprapatella	Anthropometric sitting position; arms relaxed at sides	Adjust the footrest so that the subject's knees are flexed 90 degrees, and her feet in line with her thighs. She should be able to fit the width of her three middle fingers (held together) in between the front of the seated table and the backs of her knees. Stand at her right side, place the base of the half anthropometer on the level footrest and draw the blade up to measure the vertical distance between the footrest surface and the suprapatella landmark on top of the knee.
Lower thigh circumference	Steel tape	Suprapatella	Anthropometric standing position; weight evenly distributed; knees unlocked	Kneel at the right of the subject and ensure that she has not locked her knees. Draw the tape around the horizontal circumference at the level of the right suprapatella landmark. Do not allow the tape to compress the skin.
Menton-Sellion length	Sliding caliper	Menton; Sellion	Seated; head facing straight forward; teeth unclenched; eyes closed if so desired	Stand in front and to the right of the seated subject and check that her teeth are together, but jaw is relaxed. Using the blunt-tipped side of the sliding caliper, anchor the fixed blade on the sellion landmark at the nasal depression. Slide the other blade down so that the tip lightly touches the menton landmark on the bottom of the chin, and measure this vertical distance.
Neck circumference, base	Steel tape	Lateral neck, right and left	Anthropometric standing position; head in the Frankfort plane, right hand holding the tape in the front of the neck	Stand behind the subject, and draw the tape up her chest until the tape "catches" at the lateral neck landmarks. Ask the subject to lightly hold the tape at the front of her neck, and measure the horizontal circumference around the base of the neck.

Measurement	Anthropometric equipment	Landmarks	Position of subject	Description
Popliteal height	Half anthropometer	None	Anthropometric sitting position; arms resting at sides	Adjust the footrest so that the subject's knees are flexed 90 degrees, and her feet in line with her thighs. She should be able to fit the width of her three middle fingers (held together) in between the front of the sitting table and the backs of her knees. Stand at her right side, and place the base of the half anthropometer on the level footrest and draw the blade up to measure the vertical distance between the footrest surface and the popliteal area behind the knee without compressing the tissue. 10 mm will be added to this measurement in the database to compensate for the width of the anthropometer blade.
Sitting height	Half anthropometer	(Top of head)	Anthropometric sitting position; arms flexed 90 degrees at elbows; head in Frankfort plane	Ensure that the subject is in the anthropometric sitting position. Firmly place the base of the half anthropometer on the sitting table and measure the vertical distance to the highest point on top of the subject's head. The hair should be compressed, and the measurement is taken at the maximum point of normal respiration.
Sleeve outseam	Steel tape	Acromion, right; Stylion	Anthropometric standing position; arms straight and relaxed at sides; palms rotated medially to face forward (anatomical position)	Stand to the right of the subject and ask her to relax her right arm by shaking it out gently, then returning it to her side. Anchor the zero point of the tape on the acromion landmark, and measure the straight distance to the stylion landmark on the wrist. The tape should be in light contact with the skin at the shoulder and wrist, but will not necessarily touch every part of the arm during measurement.
Stature	Anthropometer	(Top of head)	Anthropometric standing position; head in the Frankfort plane	Stand to the right rear of subject and move the anthropometer blade to touch the top of her head, compressing the hair. Measure the vertical distance between the anthropometer base and the highest point on the top of her head while she is at the maximum point in her normal respiratory cycle.
Thigh circumference	Steel tape	Gluteal furrow point	Standing; legs slightly apart; weight evenly distributed; right hand on left shoulder	Kneel at the right side of the subject and pass the tape over the drawn gluteal furrow point to assess the horizontal circumference around the top of the right thigh. Do not compress tissue or allow the tape to be positioned in a furrow.
Thigh clearance	Half anthropometer	(Highest point on the thigh)	Anthropometric sitting position; arms relaxed in lap; knees parallel and flexed at 90 degrees	Ensure that the footrest is correctly adjusted to allow the subject's knees to flex at 90 degrees. Measure the vertical distance between the surface of the seated table and the highest point on the subject's right thigh by brushing the anthropometer blade laterally along the thigh to determine the maximum height.

Measurement	Anthropometric equipment	Landmarks	Position of subject	Description
Thumbtip reach (3 trials)	Horizontal wall scale	(Thumbtip)	Standing in a corner; feet together with heels on a line 200 mm away from the wall; shoulders and buttocks against the wall; right arm outstretched against the wall chart	Position the subject's heels and have her lean back to rest her shoulders and buttocks on the wall. Ask her to hold her right arm against the wall scale and parallel to the floor. Let the thumb extend on the arm's axis, and curl the other four fingers down to touch the thumb. Stand in front of the subject and use your left arm to push back on her right shoulder, keeping it in the corner. Have the subject reach forward against the chart while maintaining her shoulders against the wall. Mark the point of the maximum distance of her thumbtip on the scale, and let the subject relax while writing down the horizontal distance. Reposition the subject and perform this measurement a total of three times.
Vertical trunk circumference, U.S. Army	Steel tape	Right bustpoint/thelion; midshoulder; posterior buttock	Anthropometric standing position; legs slightly apart	Stand behind the subject and hand her the zero end of the tape through her legs. Ask the subject to bring the tape up to her chest over her right bustpoint, and lightly anchor it above this point. Position the other end of the tape so that it passes over the right posterior buttock and right midshoulder landmarks. Measure the vertical circumference where the two ends of the tape meet at the maximum point of the subject's normal breathing cycle. The tape will not touch the skin in all areas of the circumference and should only have light contact in those areas it does.
Waist circumference, natural indentation	Steel tape	Waist (nat'l indent), right and left	Anthropometric standing position; arms resting slightly away from the sides	Measure the horizontal circumference around the waist at the level of the natural indentation landmarks. Use the mirror to ensure that the tape is level across the subject's back, and allow the subject to breathe normally for several cycles before taking a reading at the maximum point of respiration. The tape must only lightly touch the skin.
Waist circumference, omphalion	Steel tape	Waist (omphalion), right and left	Anthropometric standing position; arms resting slightly away from the sides	This measurement is taken in the exact same fashion as waist circumference, natural indentation, except that it defines the horizontal circumference of the waist at the level of the omphalion, or navel.
Waist height, omphalion	Anthropometer	Waist (omphalion), anterior	Anthropometric standing position; arms resting slightly away from the sides	Stand or kneel in front of the subject and firmly place the base of the anthropometer on the floor. Draw the blade up to determine the vertical distance between the floor and the center of the navel, or drawn omphalion landmark. Take the measurement at the maximum point in the subject's normal respiratory cycle.
Weight	Electronic scale	None	Standing on scale	Tare the scale with a standard and re-zero it before asking the subject to step on the marked footprints. Allow several seconds for the scale to register and record the weight.